

Constructivist Metaphors of Learning Science

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ABSTRACT: Based on an analysis of a fundamental distinction between metaphors of 'finding' versus 'making' for the obtaining of new knowledge, a number of constructivist positions in education are discussed and criticised, taking account of earlier criticism particularly by Suchting and by Matthews. Constructivist claims which are denied include the claim that we have no direct access to the world, and the claim that communication is inherently meaningless. What is valuable in constructivism, namely the insistence on active learning, on respect for the pupil's own thinking, and on the high priority needed for ideas taught to make sense to pupils, together with the reminder that science is a human product, is important to retain without its additional and ill-founded philosophical baggage.

MAKING OR FINDING

Ways of thinking about things generally rest on some fundamental metaphorical basis. In the case of learning and understanding science, a key metaphorical shift has been from knowledge imagined as *found* to knowledge imagined as *made*. This shift underlies the many varieties of constructivism, including both the 'social construction of reality', and the several forms of 'constructivism' which are currently recommended as a way of thinking about learning (examples include Novak 1977; Driver and Oldham 1986; Millar and Driver 1987; von Glasersfeld 1987, 1989; Driver 1989).

Consider briefly the different implications of the two metaphors for new knowledge.

To *find* is often to *see*, though occasionally things are found by groping in the dark. What is found existed before it was found. What is found is not wholly predictable in advance; it will usually surprise the finder to some extent, unless the finding is just a matter of retrieving the already known. It may or may not be 'just what one was looking for'. What is found can be lost, but if so is still there to be found again. The finder is normally receptive and attentive: it helps to know what one wants to find. However, things are also often found accidentally. What is found can only be what it is. The finder is not responsible for what it is, and it will be the same if found by another. The finder may however claim merit for having recognised the thing found as interesting, useful or important.

To *make* is not at all to look for the product, though one may need to look for the materials, since making requires malleable material ready to hand. What is made did not exist before it was made. It may be made according to plan or it may be cobbled together (what the French call

bricolage), but in either case has some element of purpose. What is made can only to a limited extent surprise the maker, usually in the sense of finding new potential in it. Once made, a thing can be unmade, destroyed or altered. If so it is gone unless re-made. The maker is active and normally purposive; one normally knows what one wants to make. Things can not easily be made accidentally. What is made could have been made differently, indeed it seems likely that it has been or will be. The maker is responsible for what it is. The maker may claim merit for having realised the need for the thing made.

In the contrast between these two metaphors, we have much of the essence of the conflict between on the one hand empiricist, inductivist or positivist images of science, and on the other either social or philosophical constructivism. We have also, quite independently, a mirror of the conflict between views of learning, either as the giving or handing on of knowledge or as the active making of one's own knowledge.

Much of the appeal of the constructivist image of learning and understanding science comes from running together these two quite distinct matters – the nature of scientific knowledge and the nature of learning – and of passing metaphorically between them. There is plainly no necessary connection between the nature of knowledge and how that knowledge is best learned or taught, though there is an obvious consequence for what the learner needs to be taught about the nature of that knowledge. Constructivist evocations of appropriate ways of learning often treat the connection as necessary, in the sense of appealing to the same metaphor for both. Sometimes this is blatant:

... unless we assume that (students) share with the inventors and developers of the conceptual models we call science, the goal of constructing a relatively reliable and coherent model of their individual experiential worlds, we cannot lead them to expand their understanding. (von Glasersfeld 1989, p. 138).

This 'argument' is as much a *non-sequitur* as it would be to start from a claim that science is largely made by intelligent white males and to 'infer' that it should be learned largely by intelligent white males. Nothing directly follows for the learning of a poem that a poem is made in a certain way, though something may follow if one is teaching how to make poems. Equally, nothing follows directly about learning (say) the nature of gases that this knowledge was made, or found, in a certain way, though again something may follow if one's concern is to teach how to make, or find, that kind of knowledge. In the present example, the muddle is made worse by reflecting the metaphor back from learning to the making of new scientific knowledge, treating the originator of new knowledge as an isolated individual concerned only to make sense of a private world of experience. That so ludicrous an error seems to come naturally is further evidence of the power of the metaphor. Solomon (1994) similarly stresses the absence in much constructivist thought of the social dimensions of science and of learning.

It has to be said that the attempt to derive an idea of how to learn science from an idea of how to do science, without due caution, is not an error exclusive to constructivists. 'Discovery methods' have been promoted on the same basis, as have indeed the dreariest schemes of rote learning and practice, the latter making appeal to disciplines of close attention and patient study.

Constructivism gains further appeal from building into the essence of the metaphorical image of learning the notion of *activity*, so that the pupil being active is now crucial to the very notion of learning (because built in to the metaphor), not just something to be recommended on some other grounds. Since, on quite other grounds, an active role for the pupil in learning is something widely (and I think rightly) seen as valuable, the constructivist metaphor gains force from containing this notion as essential to it. Metaphors which express what one would like to be the case, as necessary to how things are, feel particularly compelling.

The constructivist story may also have special appeal to some because it presents science as 'non-objective' and 'non-authoritarian'. Gone may be the need to insist that 'this is how things are'. Gone may be the need to point out the student's error. Gone may be the problem of students' feelings of inadequacy faced with difficult and complex knowledge far from their own intuitions. Gone may be worries about the elitism of science. Gone may even be the need for the teacher to know the science to be taught. Also perhaps for some there is the appeal that this image makes science seem less dangerous than one might fear. If all knowledge is personal, subjective, revisable and fallible, nuclear bombs and global pollution might just evaporate. Rarely, however is this last emotional connection made explicit, though I have heard it said if not seen it written.

A further possible appeal is that the constructivist story offers a solution to the alienation from scientific knowledge felt by many. It offers personal ownership of knowledge, not through hard work in coming to terms with other people's strange and difficult ideas, but *by definition*: knowledge is seen as *nothing other* than personally owned from start to finish. In this way constructivist ideas define away a central problem of science education, at the cost of making what constructivists often call 'scientists' science' something of a peculiarity whose role is decidedly ambiguous, to the extent that science educators call in question the teaching of science. That such remarks will appear 'elitist' to many constructivists is a symptom of the disease.

A Philosophical Diversion

Before looking in more detail at the consequences generated by replacing 'finding' by 'making' as the metaphor for knowledge and for learning, a brief diversion into a schematic story about the history of philosophy of knowledge will clarify some of the sources of discomfort which this metaphorical shift aims to soothe.

Aristotle's idea of truths of the matter was simple: "To say of what is that it is, and of what is not that it is not, is true". Amazingly, over centuries of philosophical debate many have argued themselves out of so obvious a point, to the extent of not wanting to speak at all of "what is". For Aristotle, one looked and said what one saw. This was knowledge as pure 'finding'. 'Making' was excluded because, as Matthews (1994, ch. 6) points out, Aristotle saw interfering with nature (i.e. experimenting) as disturbing the natural course of events and clouding one's view of how things are in themselves. Bacon of course took the contrary view, recommending torturing nature to reveal her secrets.

Aristotle (unseduced by the Cartesian myth of a dualism between mind and matter) was not troubled by difficulties about how to bridge the 'gap' between mind and material Nature so that our ideas can correctly reflect the nature of objects in the world. Neither are we in everyday life when for example we taste a peach. We reckon to think of it as it is. And we certainly think of it as 'out there', able to be known as directly as anything could be known.

The rise of rationalism in the seventeenth century, well exemplified by Bacon and by Descartes, gave a new emphasis to *certainty*. Oakeshott (1962) suggests that perhaps this had to do with the decline in belief in Providence: if Providence could not now provide guarantees of certainty the intellect must step in to do so. Rorty (1991, p. 87) makes the same point. Descartes looked for a method which would yield knowledge possessing the quality of certainty. His strategy to achieve certainty was to attempt to build on foundations of certainty, to start only with that of which he was sure and to allow no uncertainty to creep into the construction thereafter. This image of building well on solid rock has been pervasive. The British empiricist version of the same strategy was again to seek certainty at the start, but now in the immediate impressions of the senses; a strategy that survived until the logical positivists. Hume however dealt the strategy a fatal blow, showing how impossible it was to make a world of existing objects out of sense impressions. Berkeley had dealt a counter-blow, arguing that if sense impressions were the material of knowledge, then the known world was in the mind, not 'out there'. Kant argued that there must be something in our minds that structured what we count as 'direct' experience. Here was the beginning of the idea of 'making' rather than 'finding'.

It is the insistence on certainty, all the way through from the start, that is the key crippling move. Its most serious effect is the confusion between the existence of a thing and knowledge of it. It seems indeed almost impossible to rid oneself of identifying a lack of sure and certain knowledge about something with doubt about its existence. In most such arguments, the permanence of existence of objects and the independence of their existence from what we happen to think about them are used as metaphors for absolute knowledge of them. The absoluteness, and so the unchangeability, of the supposed knowledge is taken metaphorically from

their solid and unalterable existence. The very term 'objectivity' plays the same metaphorical game: knowledge as something object-like. At all events, statements about existence were treated as reducible to statements about knowledge – what Bhaskar (1978) calls the *epistemic fallacy*.

Worse, the metaphor makes absolute certain knowledge seem to be something it is rather reasonable to think about or wish for, whose absence is much to be regretted. It makes expressions like 'as certain as one can reasonably be', perhaps arrived at after long and arduous investigation of every imagined alternative, seem mealy-mouthed and feeble; not the real thing at all and guaranteeing nothing. The unattainable 'best', as so often, drives out the attainable 'better'. Rather obviously, absolute certain knowledge is a pure fantasy, exposed by pointing out that it involves claiming to know what anyone must think in (say) a million years from now (an especially implausible claim in respect of knowledge created in the last few years). When Putnam (1981) decries the 'God's Eye View' of knowledge, he is evidently right: the surprise is that anyone should think it a novel insight.

Thus we reach the remarkable position that denying absolutely certain knowledge of anything is taken to mean, variously, either that nothing exists except in our minds, or that if things do exist we know nothing 'directly' about them. The simple idea that things exist but we know little and fallibly about them is excluded (since 'know' is limited to mean 'know absolutely once and for all'). The idea that being as certain as one can reasonably be is an arduously worked-for achievement is shut out by thinking of certainty as only ever to be built, in Cartesian style, into the foundations.

SOME CONSTRUCTIVIST CONFUSIONS

Suchting (1992) provides a lethal attack on the emptiness of some constructivist writing, in particular dissecting a particular paper by von Glasersfeld (von Glasersfeld 1989). He shows how von Glasersfeld's argument confusedly passes over unrecognised many problematic connections and relations: how it identifies 'immutability', 'certainty' and 'objectivity' as if these were obviously the same; how 'construction' is introduced without being given any meaning; how in its use of the idea of 'experience' the argument amounts to rather orthodox empiricism written in different words; how 'reality' and 'experience' are confounded. He draws attention to the irony that in relying on support from Vico, a philosopher whose thought somewhat parallels that of Berkeley, von Glasersfeld is calling in aid of science education one who, like Berkeley, was actually concerned to stem the dangerous tide of science which he saw rising. Suchting ends with the suggestion that the root of the confusion is simple, consisting in welding together the traditional empiricist idea that the object of knowledge is directly given in experience with the opposed idea that the object

of knowledge is given only via 'constructs', by confusing 'experience' with 'constructs', so coming to assert unintelligibly that experience is a mental construct, and identifying experience and reality.

One may perhaps object to certain of the tactics Suchting adopts. For example, it seems hardly proper, as he does, to spend an entire page of his paper analysing word by word the first dozen words of von Glasersfeld's abstract, without even acknowledging that this is what is going on. Abstracts are not usually the place to find carefully nuanced pronouncements.

Matthews (1994, ch. 7) develops a point suggested by Suchting. It is that the empiricism faulted by, but nevertheless confusingly still retained by, constructivist writing is still the empiricism of Aristotle, in which objects in the world 'enter the mind' in some 'direct' fashion. He reminds us that ever since Galileo, science has largely taken a different tack, constructing idealised theoretical models prior to using these to apprehend a reality whose appearance does not directly suggest them. His example is the pendulum: no pendulum, made of a point mass on an inextensible string, was ever seen swinging isochronously for ever; yet this is the means constructed by Galileo to understand actual pendulum motion. That is, constructivist thinking ignores a kind of work of construction specially characteristic of science; the construction of theoretical objects of knowledge.

Both argue in effect that confusion arises in constructivist thinking when 'information from the senses' is still treated in good old empiricist fashion as the source of knowledge, but now seen as without meaning until actively worked on by thought, and so as not able to 'carry the real world into the head'. The empiricist idea that there must be a simple source of knowledge, guaranteed infallibly connected to the external objects of which it gives knowledge, is retained in the sense of keeping the same source whilst denying that it has the required secure connection to reality. The alternative, that building up some degree of certainty requires not an error-free source but *extended work*, checking and cross-checking, investigating alternatives, following up hidden consequences, and so on, is never noticed.

The loose collection of positions under attack here may conveniently be called 'educational constructivism', to distinguish them from other, better thought-out philosophical constructivist positions. It is particularly unfortunate that von Glasersfeld's account of educational constructivism presents itself as a plain exposition of the constructivist thinking of Piaget, whilst actually being a deformation verging on a parody of his ideas. Piaget himself can (though neither Suchting nor Matthews note the fact) be exempted from the crude errors which they identify. Piaget can certainly be labelled a constructivist, but one whose concern was to build an epistemology that was neither empiricist nor rationalist; that was realist without denying the active nature of intelligence. Indeed, Piaget provides just what the deformed account of his ideas lacks, a means for the world

to enter the mind. It is through action on the world. So for Piaget, the person exists as a real biological entity in a real physical world, and constructs mental structures to deal with that world through internalising actions on and of the world as schemes. In this way Piaget tries to escape Cartesian dualism, empiricist sensualism and rationalist idealism.

Piaget is not the only constructivist philosopher. It is remarkable that educational constructivist writing rarely if ever (I have noticed no examples) mentions the neo-pragmatist American thinking, deriving from James and Dewey and developed by Davidson, Putnam, Goodman and Rorty, all reacting to some extent to Quine (see e.g. Quine 1960, 1981; Davidson 1980, 1984, 1986; Putnam 1975, 1981; Goodman 1978; Rorty 1991). Of these it is perhaps Goodman who is the unacknowledged parent of much educational constructivism. None of them, Goodman included, suffer from the confusions of educational constructivist thinking discussed here.

The foregoing may give the impression that, with a little patching up of rigour of argument, the educational constructivist position may be got into better shape. I believe, however, that the confusions in it are not minor technical matters but have instead the much deeper metaphorical roots alluded to above. This idea can be illustrated by a number of examples, some taken from Matthews (1994, ch. 7). Crucial to all of them are the tensions between the metaphors of *finding* and *making*.

Such (constructivist) approaches view knowledge as personally and socially constructed, rather than 'objective' and revealed; theories as provisional not absolute. (Millar and Driver 1987, p. 57)

The root idea here is that what is 'made' could have been different, where what is 'found' could not. The false identification of objectivity with absoluteness is needed to stiffen the contrast. No thought is given to the possibility that what it is possible to 'make' in scientific thinking may be so highly constrained that few, perhaps no, real alternatives are available. What might we make in place of atoms?

Science as knowledge is an intellectual construct, and what are referred to as the laws of nature are merely the result of this human activity. Nature as such does not have laws. (Nadeau and Desautels 1984, p. 19)

What is 'made' is not to be imagined as existing before it was made, so if laws are 'made' they were not there beforehand to be 'found'. Also, what is 'made' is composed of the stuff of which it is made; if this is mental stuff (intellectual) it can not be physically existent stuff. The effect is to deny, absurdly, that nature is constrained in any way. The word "merely" seems to signal the contingency of human making.

Although we may assume the existence of an external world we do not have direct access to it; science as public knowledge is not so much a discovery as a carefully checked construction (Driver and Oldham 1986, p. 109).

Put into simple terms, constructivism can be described as essentially a theory about the limits

of human knowledge, a belief that all knowledge is necessarily a product of our own cognitive acts. We can have no direct or unmediated knowledge of any external or objective reality. We construct our understanding through our experiences, and the character of our experiences is influenced profoundly by our cognitive lens. (Confrey 1980, p. 108)

It is common, in order to deny the 'finding' metaphor, to claim lack of 'direct access' to reality. What a good thing it is that ships' captains and famine relief agencies presume that they have direct access to the external world! That we act causally on reality, eating bread and damming streams, and that reality acts causally on us, blowing down our houses or parching our crops, is simply ignored. Action, as 'direct access' to things, is left unnoticed. The brute constraints of reality, into which we continually bump, are ignored. In opposing 'making' to 'finding', through denying the possibility of 'finding', the simple notion that we might make ideas about what we find that we can do and what we find that nature can do is squeezed out.

The denial of 'direct access' to the physical world is either false, in that we do have causal access to it, an access which results in many of our beliefs about it being true beliefs (Davidson 1984, 1986), or it is a category mistake, amounting to denying something which cannot even be supposed, namely that the physical world whispers stories in our ears about what it is like. The required relation to the world of our beliefs about it is not provided by some impossible epistemological guarantee but by the fact that they are the beliefs of real live human beings engaged in causal interaction with the world (Rorty 1991).

There is also a different level, that of 'finding' understood as 'seeing' in the Aristotelian sense, which is being recruited here for implicit denial. We certainly do not 'see' viruses, molecules or magnetic fields, to take three decent candidates for inhabitants of reality. But if all 'finding' were simple 'seeing' then the Sherlock Holmes novels could not have been written, let alone modern science.

From a constructivist perspective, knowledge originates in the learner's activity performed on objects. But objects do not lie around ready made in the world, but are mental constructs. (Wheatley 1991, p. 10)

Here again, 'finding' and 'making' collide, with 'making' made dominant. If this were all, knowledge would be made by acting only on made knowledge, going around in a circle. Those objects which do lie around ready made in the world, like sticks and stones, would be irrelevant to the development of knowledge.

Sometimes the problem of turning everything into 'making' presents real problems to the educational constructivist. One is the account given of the simple event of a pupil being told something. Von Glasersfeld even feels obliged to deny that any communication has meaning, in order to present the meaning as needing wholly to be made by the child. This he does by a specious appeal, as if to a natural fact, to the way Shannon's

information theory defines the information in physical signals without using the concept of meaning:

The technical model of communication . . . established one feature of (communication) that remains important . . . The physical signals that travel from one communicator to another – for instance the sounds of speech and the visual patterns of print or writing in linguistic communication – do not carry or contain what we think of as ‘meaning’ . . . this feature of communication is of particular interest because it clearly brings out the fact that language users must individually construct the meanings of words, sentences and phrases. (von Glasersfeld 1989, pp. 131–132)

It is a technical strength of Shannon’s theory of communication that he found a way to define the amount of information in a message in a way which pays no regard at all to the meaning or form of the message (and so allows one to compare the channel capacities needed for the transmission of pictures by TV, for telephone messages and for computer file transfers). But the existence of such a definition says, by design, absolutely nothing about a theory of meaning, and in particular does not assert that signals lack meaning. All it says is that the channel capacity needed to transmit a signal can be calculated independently of its meaning. (One might also complain, in parenthesis, that to fail to distinguish ‘language’ from ‘speech or writing’, as von Glasersfeld does, is linguistically mistaken.)

Thus a totally deformed image of meaningful communication is evoked, without foundation. So important is it to shore up the metaphor of ‘making’ that obvious facts of everyday talking are denied, notably that people hear the meaning and not the words, that linguistic acts are meaningful interpersonal actions and not morse code, that meaning derives from social interaction, and that meanings are, of all things, not individually and personally constructed.

This deformation leads some educational constructivists to two absurdities: to deny that telling could have any role in teaching, and to treat anything which pupils do or which happens to them as ‘sensory input’ on a par with taste or smell. As to the first, it is even sometimes asserted that, ‘strictly speaking, it is impossible to convey an idea just by telling’. As to second, the muddle is well illustrated by:

The sensory input (of science lessons) can be clearly specified (e.g. reading a scientific text), or consist of a full range of sensory input (e.g. the science laboratory experiment) . . . (Osborne and Whitrock 1985)

To conflate reading things, being told things, and trying out or experimenting on things, not to mention discussing things, all as ‘sensory input’, is to deny a perfectly good term any sensible use.

Educational constructivism is largely individualistic in nature. The ‘making’ is all to be done by single persons, each required to construct the universe for themselves. And this image is applied, by running together the ‘making’ metaphor for the creation or discovery of new scientific knowledge with the same metaphor for learning it, so that scientist and

child are identified (note that Driver and Oldham do hint above that there is more to it than that). Von Glasersfeld makes scientific knowledge individualistic even in the act of recruiting Kuhn (as anti-individualistic a thinker as one could easily find) to his cause:

... a different view of knowledge has emerged ... (which) discards the notion that knowledge could or should be a representation of an observer-independent world-in-itself and replaces it with the demand that the conceptual constructs we call knowledge be viable in the experiential world of the knowing subject. (von Glasersfeld 1989, p. 122)

In these kinds of ways, the metaphor of 'making' identifies scientist and student, and scientific knowledge and personal knowledge. Certain awkward turns of phrase are needed to maintain the illusion, notable the frequently used expression 'scientists' science'. Popper's (1979) distinction between subjective individual knowledge and objective public knowledge – objective in the sense that its existence depends on no person – might never have been made.

One might summarise the educational constructivist epistemology by saying that it is a strange mixture of idealism and empiricism. It is idealist in insisting that new ideas can only be constructed from ideas we already have, but empiricist in supposing that the ideas we already have came somehow from 'experience'. The same dual face is shown in its discussion of science: Kuhn is invoked in aid of the idea that science is a human fabrication not given directly by empirical data, but the only connection of science to reality on offer is still an individualistic empiricism. So we end up with science as individual scientists' multiple and necessarily different attempts to make personal and private sense of the world.

THE VALUE OF CONSTRUCTIVISM

One should see educational constructivism in its historical context. That context is one in which centuries-long idolatry of science as 'the one true knowledge' is quite properly under attack and also one in which the question of what it could mean to educate all citizens in a knowledge known and practised by only a few is both urgent and unresolved. The wish, common to much current thought, to demythologise science is pursued by trying to show that scientific knowledge has no special character distinguishing it from any other. The option of thinking of it as a specialised knowledge required by a small fraction of the population is closed off by the terms of educational debate about a science education for everybody. And attempts to tell most future citizens the stories of science, or to train them in scientific thinking, are widely seen as having met serious difficulties, not least that most people don't seem to understand science, let alone like it. Thus one may have sympathy for the attempt even if one sees the solution as deeply flawed.

Several key positions taken by educational constructivists seem to me

to be plainly right and to be worth insisting on. Others seem to me to be plainly wrong and ripe to be jettisoned as rapidly as possible. To distinguish the two as clearly as I can, I shall list them as brief statements below.

The ideas which seem to me to be wrong or confused are:

- To insist, wrongly, that science is a collection of arbitrary stories in the mind, with no serious relation to a reality independent of us.
- To insist, wrongly, that activity in making sense of reality for oneself is absolutely the only process or goal of importance in learning.
- To identify, wrongly, the process of gaining (to use a word neutral between 'finding' and 'making') new knowledge by a scientific community with the learning of such knowledge once made public and objectively existent.
- In wrongly identifying scientist and learner, to revert to a radical individualism about both public and personal knowledge and its acquisition.
- To suggest, partly in the interests of demythologising and 'democratising' science, and partly out of a mistaken form of 'respect' for the child, that any ideas which 'make sense of the world' for one person may be as good as any others.
- To insist totally on the validity of the 'making' metaphor, and to deny any role to metaphors of 'finding', 'seeing', 'telling' or 'showing'.
- In so doing, to deform reputable sets of ideas (e.g. those of Piaget or of linguistics) so that 'making' is everything.
- To jump illegitimately from the reasonable thought that the mind is active in acquiring knowledge to the false conclusion that we cannot know reality, by making 'knowing reality' an unattainable fantasy of having absolutely certain knowledge.
- In this, therefore, to play fast and loose with useful terms such as 'reality', 'objectivity', 'truth', 'experience', notably committing the epistemic fallacy of reducing existence to knowledge.

Against these must be set a list of substantial ideas which have very positive value, and on which I think educational constructivists are right to insist. These valuable ideas ought not to be lost from sight amidst the criticisms of other ideas. I think that educational constructivists do correctly insist on four essential points:

- The importance of the pupil's active involvement in thinking if anything like understanding is to be reached.
- The importance of respect for the child and for the child's own ideas.
- That science consists of ideas created by human beings.
- That the design of teaching should give high priority to making sense to pupils, capitalising and using what they know and addressing difficulties that may arise from how they imagine things to be.

It appears to me that this second list of four essentials is also what constructivism means to many people, and that it is the value and good

sense of these four points, not all of them always recognised in the past, which has helped constructivists to convince many people of their case. If this is what constructivism means to one, there need be no quarrel and if the label 'constructivist' is felt suitably to encapsulate just these ideas without implying more, then why not use it?

Those for whom the above four items are the key elements do not need them to be shored up by the remainder, and would be best sticking to promoting active learning, respecting children's thinking, seeing science as made by humans, and trying to mesh what they say to children and what they provide for them to do with patterns of the children's current thinking, without getting into the quagmire of the rest. Nor need the metaphor of 'making' knowledge be dismissed, either in connection with learning or doing science, though its value is different in each. To make knowledge one's own is crucial, though not at all a simple or quick process, for satisfying learning. And this becomes more important when what is to be learned has been both made and found by others, in a process in which the achievement of as great a certainty as it is reasonable to want or expect, has required hard work which may be difficult to follow, and has had outcomes which can be hard to understand or appreciate.

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